Drowning
An Immersive Update

Michael Sheeser, MD
Emergency Medicine
May 2, 2024
No Disclosures
Objectives

Terminology Update
Pathophysiology
Stages of Drowning
Management
Special Circumstances

Simplified
Hypoxemia
Submersion time is Predictive
Kids and Cold water
“The process of experiencing respiratory impairment due to submersion or immersion in liquid.”
Near  Secondary
Dry  Active
Fresh v Salt
Drowning

Fatal

Non-fatal

- W Morbidity
- W/o Morbidity
<table>
<thead>
<tr>
<th>Severity of respiratory impairment after the drowning process stopped&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Morbidity category (based on any decline from previous functional capacity&lt;sup&gt;c&lt;/sup&gt;) at the time of measurement&lt;sup&gt;d&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Mild</td>
<td>(2) Moderate</td>
</tr>
<tr>
<td>Breathing</td>
<td>Difficulty breathing AND</td>
</tr>
<tr>
<td>Involuntary distressed coughing&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Disoriented but conscious</td>
</tr>
<tr>
<td>AND</td>
<td></td>
</tr>
<tr>
<td>Fully alert</td>
<td></td>
</tr>
<tr>
<td>(3) Severe</td>
<td></td>
</tr>
<tr>
<td>Not breathing AND</td>
<td></td>
</tr>
<tr>
<td>Unconscious</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>There must be evidence of respiratory impairment to be classified as a nonfatal drowning.

<sup>b</sup>The following descriptors serve to better characterize the meaning of “involuntary distressed coughing”: coughing up liquid/moving liquid out of the airway; in water, in distress and coughing; sustained coughing.

<sup>c</sup>The phrase “previous functional capacity” includes the person’s cognitive, motor, and psychological capacity.

<sup>d</sup>The morbidity category at the time when nonfatal drowning information is gathered. For the purposes of this categorization framework, morbidity is defined as a decline from the individual’s functional capacity prior to the drowning.
Submersion v Immersion
Submersion v Immersion
Fig. 2 – Map showing the countries where the papers which informed this review originated. The legend in the bottom right-hand corner indicates the number of cases reported from each region. It illustrates that there are minimal published papers from the developing countries, where the burden of drowning is highest.
WHO

Under-reported

14-30x

40/hr/day
DEATHS AT THE HUNTINGTON GORGE

Eighteen people drowned here between 1950 and 1994. Most were swimmers caught by treacherous and deceptive currents that pulled them over the falls or sucked them down to the bottom of pools. Among those who drowned:

Marjorie, age 21, 1950
William, 16, 1961
Brian, 20, 1969
Robert, 19, 1969
Daniel, 19, 1969
Robert, 21, 1971

Robert, age 25, 1972
Dennis, 19, 1973
Rosemary, 22, 1975
Michael, 21, 1976
Carol, 21, 1976
Charles, 24, 1976

Carathray, age 24, 1976
Scott, 18, 1983
Kevin, 21, 1992
Gary, 35, 1992
Cathy, 56, 1994
Peter, 32, 1994
Spit/swallow
Conscious breath holding
Sudden deep breath
Aspiration (+/- laryngospasm)

Hypoxemia
Apnea

Tachycardia
Bradycardia
PEA
Asystole
Aspiration

Toxicity/Inflammation

Surfactant Washout

Bronchospasm

Pulmonary edema

Atelectasis

Shunting + Decreased Compliance

(?)
Help...

Submersion time = Mortality

Yo, I'm hypoxic already—hustle up!
<table>
<thead>
<tr>
<th>Time Range</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 min</td>
<td>10%</td>
</tr>
<tr>
<td>6-10 min</td>
<td>56%</td>
</tr>
<tr>
<td>11-25 min</td>
<td>88%</td>
</tr>
<tr>
<td>&gt;25 min</td>
<td>100%</td>
</tr>
</tbody>
</table>
Water Rescue
Circum-rescue Collapse

Venous Pooling
Loss of oncotic/hydrostatic Pressure
Loss of catecholamine surge
Cardiovascular collapse
Management (Scene)
Figure 1. Algorithm: Classification of ND/D (Szupilman et al., 1993). The initials RPAP (Respiration⇒arterial Pulse⇒pulmonary Auscultation⇒blood Pressure) help in memorizing the sequence to follow in assessing the classification.
Figure 3 – Drowning severity classification and flowchart strategy decision based on evaluation of 87,339 rescues. Recovery position is the lateral decubitus position. CPA = cardiopulmonary arrest.
Figure 3 – Drowning severity classification and flowchart strategy decision based on evaluation of 87,339 rescues. Recovery position is the lateral decubitus position. CPA = cardiopulmonary arrest.
Water Rescue ➔ Grade 1

10-93

ED Visit?
Observe: 4-6 hrs

CXR?
Grade 5 → Dead

“No answer”

Pulse present/absent

Submersion time

Open the airways and check for ventilation (look, listen, and feel for respiration)

If not breathing
Give 5 mouth-to-mouth breaths and check for carotid pulse or signs of circulation

Pulse absent

Submersion time > 1 h or obvious physical evidence of death

Yes

Dead 100%

No

Grade 6 88%-93%

Grade 5 31%-44%

Do not resuscitate. Follow to the morgue

Start CPR (ABC sequence 2 x 30) until normal cardiopulmonary function is restored, ambulance arrives, or lifeguard exhaustion. After successful CPR, the victim should be observed as close as possible because another CPA may occur in first 30 min

Keep ventilation. Respiratory arrest usually reversed following < 10 imposed breaths. Following return of spontaneous ventilation, treat as grade 4

Forensic evaluation

ICU
C-A-B

*High performance CPR*
A-B-C

Open Airway

5-10 Rescue Breaths (O2)

CPR: 30/2
Distractions...
• Immersion Syndrome
• Malignant Dysrhythmia

4.5-6%
Trauma

C-Spine

0.5%

Watson, J Trauma 2001
Figure 3 – Drowning severity classification and flowchart strategy decision based on evaluation of 87,339 rescues. Recovery position is the lateral decubitus position. CPA = cardiopulmonary arrest.
Check for cough and abnormal lung auscultation

- Rules in some pulmonary fields
  - Grade 2
    - 1%
  - Low-flow oxygen. Warm and calm the victim. Hospital observation from < 6 to 48 h
  - ED

Grade 2

ED:
- Observe: 4-6 hrs
- Admit: 4-48 hrs
Grades 2→4

**Respiratory Therapy?**

**Admission**
- Floor/ICU

**ABX/Steroids?**

Check for cough and abnormal lung auscultation

**ACUTE PULMONARY EDEMA**
(large amount of foam)

Hypotension or Shock?

- **YES**
  - Grade 4
    - 18%-22%
  - Administer high-flow oxygen by face mask or orotracheal tube and mechanical ventilation
  - Monitor breathing as respiratory arrest can still occur. Start crystalloid infusion and evaluate vasopressor

- **NO**
  - Grade 3
    - 4%-5%
Respiratory Therapy...
in the ED/ICU

O2
HFNC
NIPPV
MV
Respiratory Therapy... in the ED/ICU

O2
HFNC
NIPPV
MV
Table 3  Outcomes of non-invasive ventilation in drowning

<table>
<thead>
<tr>
<th>Study</th>
<th>Outcome measured</th>
<th>Outcome</th>
<th>Confounders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modell et al. [16]</td>
<td>Mortality</td>
<td>24 spontaneously ventilating patients received intermittent positive end expiratory pressure 10/90 (11%) died</td>
<td>Not controlled for other interventions; outcomes not group specific</td>
</tr>
<tr>
<td>Dick et al. [40]</td>
<td>Mortality</td>
<td>11/18 (61%) NIV, 2/18 (11%) died</td>
<td>Not controlled for other interventions; outcomes not group specific</td>
</tr>
<tr>
<td>Cerland et al. [39]</td>
<td>Mortality</td>
<td>28/144 (19%) NIV</td>
<td>Not controlled for other interventions; outcomes not group specific</td>
</tr>
<tr>
<td></td>
<td>Pneumonia</td>
<td>35/144 (24%) pneumonia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ARDS</td>
<td>23/144 (16%) ARDS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>45/144 (31%) died</td>
<td></td>
</tr>
<tr>
<td>Michelet et al. [28]</td>
<td>Mortality</td>
<td>48/88 (55%) NIV</td>
<td>Not controlled for other interventions</td>
</tr>
<tr>
<td></td>
<td>Conversion to MV</td>
<td>4/48 (8%) escalated to MV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pneumonia</td>
<td>1/48 (2%) pneumonia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Duration NIV</td>
<td>1.4 ± 0.7 days</td>
<td></td>
</tr>
<tr>
<td>Michelet et al. [29]</td>
<td>Mortality</td>
<td>13/76 (17%) NIV</td>
<td>Outcomes not group specific</td>
</tr>
<tr>
<td></td>
<td>Pulmonary Complications</td>
<td>4/76 (5%) pneumonia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Duration NIV</td>
<td>15/76 (20%) died</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.3 ± 5 days</td>
<td></td>
</tr>
</tbody>
</table>

NIV, non-invasive ventilation; ARDS, Acute Respiratory Distress Syndrome; MV, mechanical ventilation

Similar outcomes

Shorter duration
Mechanical Ventilation

Given the absence of specific data on the optimal approach to ventilation, adoption of guidelines for the management of the acute respiratory distress syndrome seems reasonable.

Bierens Resuscitation 2021

6 ml/kg
Mechanical Ventilation

Weaning Considerations?
Antibiotics

12%

34-53% (d3 of MV)

Clinical Course

Bronchoscopy
Steroids

Limited Evidence

<table>
<thead>
<tr>
<th>Author, date and country</th>
<th>Patient group</th>
<th>Study type (level of evidence)</th>
<th>Outcomes</th>
<th>Key results</th>
<th>Study weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sladen A and Zauder HL, 1971, USA</td>
<td>10 fresh water near-drownings</td>
<td>Prospective (?) No corticosteroid versus methylprednisolone (5 mg/kg/24 h iv divided into 6 equal doses). Retrospective analysis.</td>
<td>Survival</td>
<td>All corticosteroid group survived, all others died.</td>
<td>Consecutive groups. Before and after study does not take account of potential change in other aspects of practice with time. Small numbers. Retrospective. No standard treatment. Not a controlled trial.</td>
</tr>
<tr>
<td>Martin CM and Barrett O Jr, 1971, USA</td>
<td>64 cases near-drowning, 29 cases drowning, 91 near-drownings (salt, fresh, brackish), (1–79 years).</td>
<td>Descriptive analysis</td>
<td>Survival</td>
<td>95 cases received corticosteroids - no benefit shown.</td>
<td>No standard treatment. Not a controlled trial.</td>
</tr>
<tr>
<td>Corbin DO and Fraser HS, 1981, Barbados</td>
<td>Retrospective analysis of charts.</td>
<td></td>
<td>No outcome measure as all were survivors</td>
<td>66 received unspecified corticosteroids.</td>
<td>Not a controlled trial.</td>
</tr>
<tr>
<td>van Berkel M et al, 1996, Netherlands</td>
<td>125 submersion victims.</td>
<td>Retrospective analysis of charts. Prednisolone (10.6 mg/kg, then 2.5 mg/kg/day; 1.8 d)</td>
<td></td>
<td>Corticosteroids: no effect on pneumonia.</td>
<td>Not controlled trial. Variable doses, ? data. Retrospective.</td>
</tr>
</tbody>
</table>

www.emjonline.com
Targeted Temperature Management

Limited evidence
Termination of Resuscitation

>30 min submersion time

>30 min asystole at normothermia.

- 0.5 min: 10%
- 6-10 min: 56%
- 11-25 min: 88%
- >25 min: 100%
Special Circumstances: Peds
3 YEAR OLD DIES FROM INJURIES AFTER FALLING INTO WATER TANK AT SMUGGLER'S NOTCH DAY CAMP
A medical malpractice lawsuit filed by the family of an Orange County girl who was revived after doctors allegedly declared her dead went to trial Monday.
NAT

38% (<5Yo in bathtub)
Special Circumstances: Cold Water
Accidental Hypothermia Protocol

**Triage & Assessment**
- **Primary survey:**
  - Airway, breathing, circulation
  - Large-bore IV access
  - Esophageal or rectal temp probe
  - Position patient on slideboard
  - Apply pads
- **HPI:**
  - Witnessed mechanism, downtime
  - PMH, code status
- ** Labs:** ABG, CBC, CMP, coags
- **Imaging:** CXR, POC echo, CT (if indicated)
  - Other: ECG

**<35°C**
- With known cold exposure & impaired consciousness

**Passive Warming**
- Warm room
- Remove wet clothing
- Apply blankets
- Warm, humidified O2

**<32°C**
- ED, ACS & CT surgery
- Attending discussion

**Triage & Assessment**
- Hemodynamically stable?
  - 1. SBP>90mmHg
  - 2. No cardiac arrhythmias
- Pulse present?
  - YES
  - NO

**>28°C**
- YES
- NO

**Active Warming**
- Forced warm air (Bar Hugger)
- Warm isotonic IVF (Belmont)
- Consider targeted temp management (Arctic Sun)
- Consider pleural or peritoneal irrigation

**Unstable, <38° and/or failing to improve**

**CPB / ECMO**

**<32°C**
- Team Activation (Call #111)
  - Attendings:
    - CTICU, MICU
    - Cardiac Anesthesia
    - Heart Failure
  - Residents:
    - CT Surgery, ACS chiefs
    - AGC, SIGU services
  - RNs:
    - SIGU, MICU charge
    - ANP
  - Teams:
    - Operating room
    - Perfusion
    - ECMO

**Any of the following MET?**
- 32°C
- K>11 (lab draw) or >9 (POC)
- >60 in avalanche victims
- Avalanche burial with snow-packed airway
- Prolonged drowning
  - >90mins in >0°C water
  - >90mins in <0°C water
- Non-compressible chest
- Witnessed arrest prior to hypothermia
- Valid/confirmed DNR status
- Excessive bleeding/thromboembolic
- Significant comorbidities, advanced age
- Irreversible signs of death

**CONSIDER TERMINATION**

---

1. Administer 1:1 shocks as indicated for VF/VTACH: warm 1.2°C or to >30°C prior to additional shocks. Dafenoxame (dextroamphetamine) 20mg until 30°C. Double the dosing interval when 30-35°C.
Video shows Vermont state troopers rescue a child from frozen pond

PULLED FROM THE ICE

STATE TROOPER RESCUES CHILD FROM FROZEN POND
Termination of Resuscitation

>30 min submersion time

>30 min asystole at normothermia.

>90 min for child <6 Yo in water <6C (43F)

0-5 min: 10%
6-10 min: 56%
11-25 min: 88%
>25 min: 100%
Kids < 4 Yo

- Supervision
- Fencing
- Life jackets
- Water safety
Young Men
- Alcohol
- Life jackets
- Boating safety
Summary

Submersion time is key

Hypoxia is the problem

Treat as ARDS

Cold water is different

Prevention
Questions?
References

Davis C. Wilderness Medical Society Clinical Practice Guidelines for the Treatment and Prevention of Drowning: 2024 Update. Wilderness & Environmental Medicine 2024, Vol. 35(1S) 94S-111S


